# Introduction to GEM

Introduction

In enhanced recovery schemes involving gas or solvent injection, the process may be immiscible or miscible depending on the composition of the injected fluid and the reservoir oil, and on the reservoir pressure and temperature. Examples of such processes are enriched gas drive, high pressure gas drive, $CO_2$ flooding, and the cycling of a gas condensate reservoir. The simulation of these processes requires special handling of both the thermodynamic and the fluid flow aspects of the reservoir.

GEM is an efficient, multidimensional, equation-of- state (EOS) compositional simulator which can simulate all the important mechanisms of a miscible gas injection process, i.e. vaporization and swelling of oil, condensation of gas, viscosity and interfacial tension reduction, and the formation of a miscible solvent bank through multiple contacts.

Some of the additional features of GEM are listed in the following.

Adaptive Implicit Formulation

GEM can be run in explicit, fully implicit and adaptive implicit modes. In many cases, only a small number of grid blocks need to be solved fully implicitly; most blocks can be solved explicitly. The adaptive implicit option selects a block's implicitness dynamically during the computation and is useful for coning problems where high flow rates occur near the wellbore, or in stratified reservoirs with very thin layers. Several options are provided for selecting implicit treatment.

Properties

GEM utilizes either the Peng-Robinson or the Soave- Redlich-Kwong equation of state to predict the phase equilibrium compositions and densities of the oil and gas phases, and supports various schemes for computing related properties such as oil and gas viscosities.

The quasi-Newton successive substitution method, QNSS, as developed at CMG, is used to solve the nonlinear equations associated with the flash calculations. A robust stability test based on a Gibbs energy analysis is used to detect single phase situations. GEM can align the flash equations with the reservoir flow equations to obtain an efficient solution of the equations at each timestep.

CMG's WinProp equation of state software can be used to prepare EOS data for GEM.

Complex Reservoirs

GEM uses CMG's Grid Module for interpreting the Reservoir definition keywords used to describe a complex reservoir. Grids can be of Variable Thickness - Variable Depth type, or be of corner-point type, either with or without user-controlled Faulting. Other types of grids, such as Cartesian and Cylindrical, are supported as well as locally Refined Grids of both Cartesian and Hybrid type. Note that Hybrid refined grids are of a locally cylindrical or elliptical nature that may prove useful for near-well computations.

Regional definitions for rock-fluid types, initialization parameters, EOS parameter types, sector reporting, aquifers, ... are available. Initial reservoir conditions can be established with given gas-oil and oil-water contact depths. Given proper data (such as from WinProp), fluid composition can be initialized such that it varies with depth. A linear reservoir temperature gradient may also be specified.

Aquifers are modelled by either adding boundary cells which contain only water or by the use of the analytical aquifer model proposed by Carter and Tracy.

Dual porosity modelling can be done with GEM. Each cell is assigned separate matrix and fracture pore spaces. Shape factors describing flow between porosities are implemented based on the work of Gilman and Kazemi. Additional transfer enhancements are available to account for fluid placement in the fractures. The GEM user can also specify a dual permeability model which allows fluid flow between adjacent matrix blocks. This option is useful when matrix-matrix mass transfer processes are important, such as in situations dominated by gas-oil gravity drainage processes.

Geomechanical Model

Several production practices depend critically on the fact that the producing formation responds dynamically to changes in applied stresses. These include plastic deformation, shear dilatancy, and compaction drive in cyclic injection/production strategies, injection induced fracturing, as well as near-well formation failure and sand co-production. A geomechanical model consisting of three submodules is available for treating aspects of the above problems. The coupling between the geomechanical model and the simulator is done in a modular and explicit fashion. This increases the flexibility and portability of the model, and decreases computational costs.

Wells

Bottomhole pressure and the block variables for the blocks where wells are completed are solved fully implicitly. If a well is completed in more than one layer, its bottomhole pressure is solved in a fully coupled manner; i.e., all completions are accounted for. This eliminates convergence problems for wells with multiple completions in highly stratified reservoirs.

A comprehensive well control facility is available. An extensive list of constraints (maximum/minimum bottomhole or wellhead pressures, rates, WCUTs, GORs, ...) can be entered. As constraints are violated, new constraints can be selected according to the user's specifications. Various actions and apportionments are available.

Up to three hydrocarbon streams can be controlled on the surface: Oil, Intermediate Liquid and Gas. Various types of surface separation facilities can be used to generate these streams, including the modelling of EOS and plant separator stages, where the latter are described using key-component tables.

The gas cycling option in GEM allows for the preferential stripping of components and the addition of a make-up gas stream to the recycling gas stream.

Matrix Solution Method

GEM uses AIMSOL, which is a state-of-the-art linear solution routine based on incomplete Gaussian Elimination as a preconditioning step to a GMRES iteration. AIMSOL has been developed especially for adaptive implicit Jacobian matrices.

For almost all applications, the default control values selected by GEM will enable AIMSOL to perform efficiently. Thus, GEM users do not require detailed knowledge of the matrix solution methods.

GEM uses run-time dimensioning as well to make the most efficient use of computer resources.

Simulation Results Files

Various types of Simulation Results Files can be written while GEM is running, including files for CMG's Results. Results is CMG's visualization software that can be used to examine 2-D and 3-D reservoir displays, as well as XY plots of important dynamic data.

Portability

GEM has been run on many computers from many manufacturers, such as IBM, SGI, and SUN, as well as PCs. Currently supported chips and operating systems are given in the Installation Guide.

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